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AEQUINOCTIA, AN OLD PALEOZOIC CONTINENT

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Through the whole of Central Celebes,¹ from the Gulf of Boni to the Gulf of Tomini, extends a formation of crystalline schists, lying east, but principally west, of Lake Posso. These schists are strongly folded and their positions vary from horizontal to vertical. More than once, but last during the Oligocene, this region was leveled by denudation. The resulting peneplain was arched during the neo-Tertiary and Plio-Pleistocene to 2,000 meters above sea-level. Consequently, it became deeply cut by erosion. In some of these furrows one can distinctly observe an east-west strike of the strata, which seems to be the effect of the oldest folding. Especially on the west of Lake Posso the region appears now as a distinct geographical entity. West of these mounts others follow, either separated from the first by depressions or not. They consist of gneiss, viz., biotite and amphibole gneiss, amphibolites, granites, and effusive rocks. In this part of the country the peneplain character has not been preserved so well; the highest tops reach altitudes up to 3,000 meters.

In no other part of the Dutch East Indian Archipelago do the gneiss and schists region occupy such a large surface as in Central Celebes; besides that, the crystalline schists are characterized by a particular richness of rock varieties.

Most of the schists belong to the second and eighth groups of the Grubenmann² classification, and to the upper and middle zones of these groups. This leads to the conclusion that they represent metamorphosed clays, sandstones, and argillaceous sandstones. Besides these rocks, a certain importance must be attributed to the metamorphosed calcareous sandstones and limestones, rocks of the

¹ See E. C. Abendanon, *Voyages géologiques et géographiques à travers la Célèbes Centrale*, 3 volumes and one atlas, Leyde, Holland, 1916-18.

² U. Grubenmann, *Die kristallinen Schiefer*, Vol. II, 1907.

ninth and tenth groups, some of them making part of the upper zone, but chiefly belonging to the middle zone. These latter varieties appear principally along the eastern bank of Lake Posso and north of the lake.

With these schists of sedimentary origin, there are others which must have evolved from more or less basic eruptive rocks and their tuffs. But for a few exceptions, belonging to the middle zone, most of these latter schists belong to the upper zone; they are represented by rocks of groups three (plagioclase gneiss), four (metamorphosed gabbroid rocks), and five (schists containing silicates of magnesia).

The age of this formation of schists in Central Celebes and in other parts of the archipelago has been interpreted as follows:

1. Wichmann¹ considers the mica schists of Central Celebes as Archean; Martin² does the same regarding those of Ceram, whereas Verbeek³ thinks that those of South Borneo constitute a series of Azoic rocks; Volz⁴ refers to the Archean only the gneiss of the land of the Gajos (North Sumatra).

2. Molengraaff⁵ believes that the crystalline schists of Central Borneo are partly Archean, partly of more recent age.

3. Verbeek⁶ groups the gneiss and mica schists which he found in the Moluccas, with other rocks, such as the quartzites (of dark color) and argillaceous schists, in the "old schists formation," in which he presumes the existence of Azoic (e.g., the gneiss of Sibellaboe) or Archean elements, but also elements of the Old Paleozoic. His opinion upon this matter is shared by Volz⁷ and Ahlburg,⁸ who also connect other rocks, such as the peridotite of eastern and southeastern Celebes, with the mica schists. Volz draws attention to the complete conformability between the mica schists and the old schists in the aforementioned land of the Gajos. It must be

¹ "Der Posso-See in Celebes," in Petermann's *Geogr. Mitteilungen*, Heft VII, 1896.

² "Reisen in den Molukken," *Geologischer Theil*, 1903.

³ *Jaarboek van het Mijwwezen*, Vol. I, 1875.

⁴ *Nord-Sumatra*, Vol. II, 1912.

⁵ *Geologische verkenningsstochten in Centraal. Borneo*, 1900.

⁶ *Rapport sur les Moluques*, 1908. ⁷ *Nord-Sumatra*, Vol. I, 1909.

⁸ *Versuch einer geologischen Darstellung der Insel Celebes*, 1913.

remarked that a similar conformability has been discovered nowhere else in the archipelago by any of the other explorers.

4. The rare true mica schists of Letti are regarded by Molen-graaff¹ as metamorphosed rocks of the Old Permian.

5. By Wing Easton,² but more expressly by Volz and Tobler,³ the "old" schists are considered as being partially Mesozoic. One may doubt, however, whether they include real mica schists.

6. Smith⁴ expresses much doubt about the Archean age ascribed to the crystalline schists of the Philippine Islands, and he assigns many of them to the Tertiary.

There is thus a strong discrepancy in the opinions of these competent explorers, as the ages they assign to the schists vary from the Archean to the Tertiary. Their opinions could hardly differ more.

In order to come to a personal conclusion, I shall begin by trying to solve a few questions. First of all: Do all the series of rocks which the above-mentioned explorers have classed with the "old schists formation," really belong to it?

It would perhaps be possible to answer this question with certainty if one had gathered into a single collection all the rocks collected; but such a collection does not exist. On the contrary, those assembled by the explorers named are scattered in such a large number of museums that a comparative petrographic examination of the crystalline schists and old schists existing in the different parts of the Dutch East Indian Archipelago is absolutely impossible. One thing is certain, however, and that is that the rocks included in the "old schists formation" have been put together on a basis of negative characters, namely, their "old" appearance and the absence of fossils. It is therefore possible, perhaps very probable, that elements have been included which in fact do not belong to the old schists formation.

In order to come to a more accurate classification, it appears necessary to make, first of all, a distinction between the gneiss and crystalline schists on the one side, and the "old" schists on the other

¹ *Jaarb. Mijnwezen*, 1914.

² *Ibid.*, 1904.

³ *Voorl. med. over de geologie der res. Djambi*, 1912.

⁴ *Handbuch der regionalem Geologie*, Philippine Islands, 1910.

side. The real gneiss must be separated from the gneissoid rocks which originated at the periphery of the younger granites at the time of their solidification. These gneissoid rocks appear in large quantity in Central Celebes, and Volz believes he has detected them in the north of Sumatra. As to the crystalline schists, it is advisable to distinguish the old mica schists from the rocks belonging to the more recent contact zones, as for instance the andalusite mica schist from Central Celebes. Finally, there is no doubt that there has been included with the "old" schists rocks¹ which do not belong to them. For instance, in his *Rapport sur les Moluques* (p. 755), Verbeek places the argillaceous schists of the island of Taliabo in the old schists formation. However, they recall so much certain schists of the Upper Cretaceous, either metamorphosed or not by the granite of the southwestern part of Central Celebes, that I can no longer consider them as being undoubtedly old schists.

Having eliminated the rocks which do not belong to them, it must be accepted that there exists in the Dutch East Indian Archipelago three series of rocks which are unquestionably of similar age, and which form the base of the other geological formations. Of these, the gneiss and mica schists are the earliest member. This double series appears as large complexes, principally in the north of Sumatra, the southeast of Borneo, on very extensive areas in Central Celebes, and in the islands of Boeroe and Ceram. As in other places, it is possible to see the lowest strata, viz., the gneiss formation, in this latter island and elsewhere in the archipelago, but especially and very clearly in Central Celebes. In its upper part, these crystalline schists seem to grade into the "old" schists, which constitute the second essential member of the oldest formations. These schists are well known in many parts of the archipelago, but only Volz has pointed out their conformability with the mica schists in the north of Sumatra.

Particularly in Central Celebes the mica schists occupy such an extensive surface, vertically as well as horizontally, that there is

¹ Tobler (and before him Wing Easton and Volz) had already called attention to this point; however, he does not exclude them systematically from the denomination "old schists."

no question of explaining them by contact metamorphism (although it is certain that such metamorphism has taken place locally). We have here to deal with regional metamorphism of ancient date. The total thickness of these schists cannot be estimated, even approximately, but it is certainly some thousands of meters. Such a thickness could not have resulted, in Celebes or in other islands of the archipelago, from the sedimentary beds of the Tertiary or of the Mesozoic. So we reach the conclusion that these rocks are pre-Mesozoic.

What is the tectonic relation between the crystalline schists of Central Celebes and those of other parts of the archipelago?

Suess¹ has remarked that Martin observed a large massif of Archean rocks in the islands Boeroe and Ceram; it consists principally of mica schists having an east-west strike. Similar rocks² having the same strike have been found, not only in the group of the Péling-Misool islands,³ but also in the northwestern peninsula of New Guinea, whereas the island of Roon (east of this peninsula) is composed of gneiss. These data have led him to the hypothesis⁴ that the islands Ceram and Boeroe are but the prolongation of the central mountain ranges of New Guinea, whereas the group of the Péling-Misool Islands and the northwestern peninsula of New Guinea represent the foreland of the folded land situated farther south. Suess makes of this foreland an old "massif" (Vol. III, Part 3, p. 1036). He would make a geological entity of the territory extending from Celebes to the little island Rossel, southeast of the southeastern point of New Guinea, but he writes (Vol. III, Part 3, p. 1035): "L'énorme distance qui sépare Célèbes de l'île Rossel (Louisiade), ainsi que les grandes lacunes dans nos connaissances, ne permettent pas d'énoncer ici des résultats certains." Further (Vol. III, Part 1, p. 343): "On ne peut pas dire de quelle façon la chaîne des îles orientées de l'E. à l'W. (Obi, Taliabo, etc.) se prolonge à Célèbes."

¹ *La Face de la Terre*, Vol. III, Part 1, p. 317.

² *Ibid.*, Vol. III, Part 3, p. 1033.

³ *Ibid.*, Vol. III, Part 3, p. 1036: "Des terrains anciens apparaissent dans ces îles (de Taliabo à Misool), surmontés de couches mésozoïques non plissées."

⁴ *La Face de la Terre*, Vol. III, Part 1, p. 318 and Vol. III, p. 1035.

As a result of the investigation made in Central Celebes, this last point is now elucidated, for the east-west strike is repeated in a very remarkable way in the schists and gneiss formations of this territory, although the older ranges of Central Celebes and Ceram have a northwest to southeast direction, owing to the post-Lutecian folding, whereas younger horsts of Central Celebes have a north-south direction, the result of more recent tectonic events. Moreover, the old massifs of Central Celebes are separated from those of the islands situated to the east of Celebes by a massif of peridotite. This latter rock has great importance in these islands.

Until the contrary is proved, the answer which one may give to the second question indicates thus that the gneiss and schists massifs, from Central Celebes to the island of Roon, are parts or horsts of an old massif which stretched formerly throughout this whole extent. Without being able to assert it dogmatically, one may say that this old massif, folded in an east-west direction, is prolonged to the west, and that it reaches the middle of Borneo, where Molengraaff and other explorers have also found tectonic entities striking almost east and west.¹

The answers given to the first two questions are not sufficient to define precisely the age of the mica schists. This leads me to look outside the archipelago and to ask the following questions: What is the distribution of the oldest formations outside the limits of the archipelago? In what places do they reveal their age with certainty by the presence of fossils? What geo-metamorphic processes have the formations in those places undergone, and what is the relation of these processes to those which have predominated in the archipelago?

If the metamorphosing processes in other places have not been more favorable than in the archipelago for the preservation of fossils of Paleozoic, and especially of early Paleozoic age,² we have one reason less for presuming that fossils once existed in the schists of the archipelago.

¹ The same direction is repeated in the northern peninsula of Celebes, in the isle of Java, and in the chain of the small Sunda Islands.

² Neo-Carboniferous and Permian fossils have been found in the archipelago; this is a well-known fact.

To answer the foregoing questions I cannot do better than again to refer to Suess's *La Face de la Terre*.

In the eastern part of New Guinea there exist old rocks much folded and strongly upheaved,¹ which occupy the highest parts of the interior, as for instance the Owen-Stanley Range, Adolf-Haven, and the southern coast of the Huon Gulf. These rocks are also found in the north of New Caledonia, along the northeastern coast, with a direction N.20°-55°E.

If we leave New Guinea and pass to Australia, we see there the large central upland mentioned by Suess, which is composed of granite, gneiss, old schists, and a very extensive mantle of the "Desert Sandstone" (pp. 243-44). It extends to the western coast of Australia, where it is abruptly interrupted. In latitude 25°15'S. on this coast a Carboniferous series has been found (p. 243).

The eastern and southeastern parts of Australia, on the other hand, consist mostly of folded mountain ranges; there we find the Silurian, which is represented in Cape York peninsula (longitude $\pm 137\frac{1}{2}^{\circ}$ E., and latitude 35°S.), separating the gulfs of Spencer and St. Vincent (p. 249). North of this latter gulf, in the Flinders Range, there are outcrops of old schists and quartzites (p. 247). Further east, the old rocks of the Barrier and Grey ranges seem to be identical (p. 247); finally comes the great Australian Cordilleras, about which Suess writes (p. 248): "Des granites, des porphyres, des terrains cristallins, siluriens et dévoniens extrêmement plissés, généralement même redressés jusqu'à la verticale, constituent le noyau de la Cordillère. ... Le Carbonifère est presque horizontal."

I draw attention to the fact that in these mountain ranges the Silurian and the Devonian, although very much folded, are still recognizable by their fossils.

Let us cursorily follow Suess in his further views on the Cordilleras. With regard to Tasmania, he writes (pp. 251-52): "Du granite, des schistes cristallins et du Silurien s'y montrent redressés presque verticalement, suivant une direction méridienne; le Carbonifère, tant sous le faciès maritime que sous le faciès continental, recouvre en discordance ces terrains anciens." In the

¹ Suess, *op. cit.*, Vol. III, Part 3, pp. 1026-30.

eastern part of Victoria one meets again granite rocks and more or less vertical formations of gneiss and strata of Silurian age (p. 252). Continuing northward, we come to New South Wales, where north-south zones of granite and strongly folded Silurian and locally Devonian beds, together with old porphyry, form the eastern coast up to the Bateman Bay (latitude $35^{\circ}40'S$). Northward this chain departs from the coast and disappears gradually under the horizontal Carboniferous (pp. 253-54). Further east another range consisting of granite and Silurian strata extends toward the north to Queensland (p. 254). In the northern part of New South Wales, the New England Range is composed of folded strata of Lower Paleozoic formations, with a nucleus of granite forming mountains (p. 254). To the north the granite diminishes, but the folded Devonian series increases (p. 255). To the west the Cordilleras disappears under the mantle of "desert sandstone" stretching to the Gulf of Carpentaria; at some points there rise through this mantle formations of granite and Paleozoic sediments (p. 255). Between latitude $22^{\circ}30'$ and $22^{\circ}S$. there are further patches of the Devonian and Silurian; but to the north of latitude $22^{\circ}S$. the coast, as far north as it is known, is formed of granite rocks, as also are the islands of the Strait of Torres, between Cape York and New Guinea (p. 256). In southeastern Australia the Silurian and Devonian, although much folded, have remained recognizable by their fossils up to latitude $22^{\circ}S$.

If we now pass to the opposite (northwest) side of the archipelago, to Southeastern Asia, what do we find? The islands of Banka and Billiton form a connection between the Dutch East Indies and the Malacca Peninsula. The granitic lands of these stanniferous islands extend in a northwestern direction over the southern point of the peninsula, in which (at Singapore) sandstones and old schists¹ have also been discovered. Just west of longitude $100^{\circ}E$. this granite chain turns to the north and ends in this direction at the island Kaw Tau, in the Gulf of Siam (Suess, Vol. III, Part 1, p. 303). To the west follows a depression in which flows the Bandon (p. 303). To the west of this depression comes another

¹ Suess, Vol. I, p. 600 and Vol. III, Part 1, p. 303. See also Verbeek, *Rapport sur les Moluques*, pp. 755-56, concerning the presence of Jurassic rocks in this series.

granite chain extending toward the north, thus forming a transition to the Birman chains (p. 303). At Tenasserim, on the neck of land east of the Mergui Islands, there are outcrops of Upper Carboniferous (p. 303) as well as of Archean rocks (I, 599). This Upper Carboniferous seems to extend far to the north in the valley of the Salwen, and at Moulmein notably (latitude $\approx 16\frac{1}{2}^{\circ}\text{N.}$), in the form of limestone, it occupies a large area (p. 599). However, this eastern zone of the Birman chains, to which we have come, consists principally of Archean rocks (p. 593). To the east of Moulmein the chains extend northward and north-northeast, beyond Xieng-Sen, which is situated on the Mekong, in the northern part of Siam (Vol. III, Part 1, p. 290). Other ranges joining the former between Xieng-sen and Vien-tiane (also on the Mekong, but further down) take a northeast-southwest direction, and, decreasing in height, gradually disappear toward the southeast and the south, under the Siamese plain (p. 290). Then toward the southeast comes Siam, an immense unknown land, which, being connected with a vast area of granulite and granite, leads us to the low and old massif of Cambodge, of which we will speak later (pp. 290-91). Let us first follow the Birman chains toward the north.

According to Griesbach, the limestones of Moulmein seem to continue northward up to the highland of the Shan, where the Permian limestone is folded, the folds having been leveled (Vol. III, Part 1, p. 281). Then long ranges composed at first of crystalline schists and further north of gneiss lead north to Mandalay on the Irawaddi. And here again, in the Northern Shan States, we find once more the oldest fossiliferous strata which we had left in latitude 22°S. on the eastern coast of Australia. In fact, Suess writes (Vol. III, Part 1, p. 278): "Le chemin de fer et la route qui, de Mandalay, ont été construits vers le N.E. par Thibaw jusqu'au bac de Kunlon¹ sur la Salouen, longent sur de grandes distances la direction (N.N.E. ou E.N.E.) des roches. Les terrains les plus anciens sont à l'Ouest; au voisinage de Mandalay se montrent les couches inférieures de la série, peut-être cambriennes, puis le Silurien inférieur, le Silurien supérieur, un grès rouge pincé dans les plis,

¹ Kun-long, just to the south of the Tropic of Cancer.

et enfin la plaine récente du Salouen. ... *Le Silurien, affecté de plis, présente une grande variété de faciès.*"¹ The Silurian fossils of the Northern Shan States have not yet been found in the above-mentioned limestone series of the southern highland of the Shan (Vol. III, Part 1, p. 281).

From Kun-long, crossing the high ranges in a northwest direction up to Bhamo on the Irawaddi, we reach the mountains of the Siang-chan, which advance toward the north (p. 277). They consist of gneiss and crystalline schists and, for a great part, of granite (p. 277). On the west these mountains border on a zone of Carboniferous strata (p. 277). Then, turning again to the northeast, in the direction of Ta-li-fou, we recross the above-mentioned mountains of old crystalline rocks, which extend nearly to the Salwen in latitude about 25°N. Between this river and Young-tchang-fou, Lóczy found at Poupiao (latitude about 25°N.) the Silurian beds, whereas more to the east (eastward of Young-tchang-fou) he discovered Upper Carboniferous strata (pp. 276-77). This folded Paleozoic zone is situated between the Salwen and the Mekong (p. 276). East of the Mekong a broad zone of sandstone presenting the facies of the Flysch leads to the range of the Tsang-chan, consisting of crystalline schists. Next follows another sedimentary zone, composed principally of Upper Carboniferous strata which extend to the north, from Tali-fou to Batang (p. 276).

We need not continue in details our travel to the north and east, but we may limit ourselves to a few remarks. In the north the Upper Carboniferous strata play a somewhat important part, stretching themselves unconformably over older folded and denuded series of the Lower Paleozoic. After their deposition, there followed a new folding and, with regard to its tectonic history, this territory offers a fair similarity to many other countries of Eurasia (p. 276). Very far in the northeast of Central China, appear on one side the gneiss and crystalline schists, and on the other the oldest Paleozoic beds, all strongly pinched in successive mountain ranges. In the west, Silurian and Devonian series predominate (pp. 266-75); in the east, next to these, there are Cambrian strata (pp. 294-95). In Central and Northern China these formations of

¹ The italics are mine.

the Old Paleozoic attain a considerable development, as has been pointed out by von Richthofen,¹ Willis,² and others, as well as myself.³ Concerning the Cambrian highland of Ordos, north of the Tsing-ling-chan, we refer also to Suess (Vol. II, pp. 303 ff., and Vol. III, Part 1, pp. 252 and 263). In that part of China unfolded Cambrian beds lie unconformably on folded and denuded Archean formations.

We need not go farther north, but now we return to Southern China, about which Suess (Vol. III, Part 1, p. 297) informs us: "Leclère⁴ signale ... près de Hoaï-yuen, au Sud-Ouest de Kouen-lin, une arête de terrains précambriens et un culot de granite, accompagné, à l'Ouest, sur le Sikiang, par des roches précambriennes." And always following Suess, we proceed back again from Ta-li-fou to Cambodge, this time by the way of Yun Nan, Tonkin, and Annam. According to him (Vol. III, Part 1, p. 287), the mountain chains divide. The western ones, the Birman chains, we have followed in a zigzag way from south to north. The eastern chains lead in a southeastern direction to the Cordilleras of Annam. Without entering into details, we may say that, between Ta-li-fou and Indo-China, the oldest fossiliferous rocks continue gradually to disappear. It is only more eastward, at Lou-nan (east of Yun-nan-fou), that Leclère recognized series of the Middle and the Upper Devonian, together with various formations of the Carboniferous and the Permian (p. 296). The tectonic relation between these rocks and those of the above-mentioned pre-Cambrian (also discovered by Leclère) cannot yet be established. We read in Suess (Vol. III, Part 1, p. 297): "Les relations de ces anciens terrains ne se dégagent pas encore avec netteté des documents publiés jusqu'à présent. Il n'est guère possible de dire

¹ F. von Richthofen, *China*, 5 volumes and one atlas; Vol. I, 1877; Vol. II, 1882; Vol. IV, 1883, atlas North China, 1885; Vols. III, V; and atlas, South China, 1911.

² B. Willis and E. Blackwelder, *Research in China*, 2 volumes and one atlas; Vol. I, 1907.

³ E. C. Abendanon, "La Géologie du Bassin Rouge de la province du Se-Tchouan," *Rev. Univ. des Mines*, etc., Liège, 1906. E. C. Abendanon, "Structural Geology of the Middle Yang-tzikiang Gorges," *Journal of Geology*, 1908.

⁴ A. Leclère, "Etude géologique des provinces chinoises voisines du Tonkin," *Annales des Mines*, 1900-1901.

s'ils auprésentent le substratum de la plate-forme calcaire comme auprès d'I-tchang¹ ou s'ils font partie du massif ancien qui existe probablement dans la Sud-Est de la Chine, en formant un avant-pays indépendant des Altaïdes."

The most recent data about a fairly considerable area of the eastern part of the Chinese province of Yun Nan are supplied by Deprat.² This explorer gives many details. He writes (p. 44):

Les terrains métamorphiques ou granitiques n'apparaissent que dans le S., dans la vallée du Fleuve Rouge. ...

Le Cambrien offre un développement énorme au Yun-Nan, aussi bien dans son extension verticale qu'horizontale; *les séries fossilifères sont abondantes*.³

J'ai découvert l'Ordovicien au N. d'Yi-léang. Le Gothlandien paraît représenté dans la même région.

Le Dévonien complet offre un développement colossal au Yun-Nan. J'ai reconnu le Dévonien inférieur. Dans le Mésodovénien, l'Eifélien et le Givétien sont bien caractérisés, de même que le Frasnien et le Famennien dans le Dévonien supérieur.

Nous avons pu affirmer la présence du Dinantien, représenté par plusieurs niveaux. Le Moscovien offre un développement énorme, ainsi que l'Ouralien.

About the relation between all these formations, Deprat goes into details, too, and he informs us that the structure of this territory is very complicated. According to him (pp. 251-60), a local orogenic movement (in the southeastern part of Yun Nan) took place after the Cambrian; there was uninterrupted sedimentation during the Silurian, and the corresponding beds ought to exist from Kwei-chow in the east to Burma in the west. The sedimentation continued until the Muscovian in well-developed series. Then there followed a strong ante-Uralian folding; the Uralian formation lies unconformably on the denuded folds of the Old Paleozoic. At the end of the Permian, when marine sedimentation came to an end and before any deposit of Lower Triassic sediments had taken place, a very intense orogenic movement occurred. After that, Deprat writes (p. 252): "La dernière

¹ Situated on the Yang-tzi-kiang, at the point separating the middle from the lower part of this river.

² J. Deprat et H. Mansuy, *Etude géologique du Yun-Nan oriental*, Vol. I, Fasc. I, 1^{re} partie, Hanoi-Haiphong, 1912.

³ The italics are mine.

phase principale de plissement, dont l'intensité a été véritablement très grande, est la phase de dislocation post-triasique, dont les effets ont été considérables; je la considère avec M. Lantenois comme une phase himalayenne: (p. 257) l'ensemble du Yun-Nan est alors plissé d'une façon très énergique, les charriages y prennent une amplitude très grande et la région du haut Fleuve Bleu (Yang-tsé-Kiang), prolongement sud du Yung-ling-chan, est charriée sur la région yunnannaise." The last movements were due to the upheaval which raised Yun Nan to the relatively high altitude which it occupies nowadays. They occurred during the Plio-Pleistocene.¹

It is clear that the tectonic movements of Yun Nan, where the excessive thick Old Paleozoic series appear on such an extensive area and with a particularly great richness of fossils, have been extremely intense and numerous.

In Northern Annam, F. Deprat² discovered at Ben-Thuy the Ordovician, and he believes that this formation will also be discovered in Tonkin and Laos. The Devonian and Dinantian are also represented in this region, and the Uralian is once more in transgression (exactly as in Yun Nan) upon a folded and denuded territory of the older Paleozoic.

In the same way as in the Northern Shan States far to the west, here in the east of Southeastern Asia we find the most southern country where fossils of the Old Paleozoic have been discovered; for according to Suess, in the plain of Tonkin soft schists have been assigned to be Devonian; but this point is far from being sure (Vol. II, p. 277). In the island of Haï-Nan, we find Suess mentioning (Vol. III, Part 1, p. 297) that according to Madrolle, the center of the island is composed of granite and schists, and is

¹ These last movements of epirogenic character, giving rise to the phenomena of what I have called anticlinal distraction (in a booklet titled *Die Grossfalten der Erdrinde*, Leyde, Holland, 1914), which phenomena led to the forming of important tectonic depressions, are so completely similar to those of the Plio-Pleistocene period in Central Celebes, where I have classified them together in a single process of grand-folding, that I do not hesitate to identify the most recent epirogenic movements of Yun Nan with those of Central Celebes, the latter having induced the upheaval of this country to its present high altitude.

² "Sur la découverte de l'Ordovicien, à Trinucleus, et du Dinantien dans le Nord-Annam, etc.," *Comp. Rend. Ac. d. Sc.*, 28-5-12, T. 154, pp. 1452-54.

surrounded by a sandy argillaceous formation of red color in the north and yellow in the east.

Patches of Carboniferous limestone occur more abundantly as we approach the Cordilleras of Annam, on the east coast. Suess mentions (Vol. III, Part 1, p. 297) that Bell crossed these Cordilleras in a westerly direction, starting from Tourane (on the eastern coast of Annam, by latitude $16^{\circ}10'N.$). They appear to be composed of various zones, first of dioritic and granitic rocks, then of gneiss and crystalline schists, and lastly of rather recent formations (Vol. II, p. 275, and Vol. III, Part 1, p. 297). The granitic rocks advance toward the south, along the coast, from latitude $14^{\circ}N.$ to Cape St. Jacques, southeast of Saigon, and they must be the southern extremity of a very long mountain chain stretching in a northern direction to the granite highland of Laos (Vol. II, p. 275).

In this way we come back to the old low massif of Cambodge and to the delta of the Mekong, in Cochin-China.

Like Australia to the southeast, Cochin-China and Tonkin constitute very old uplands (Suess, Vol. I, p. 607) to the northwest of the East Indian Archipelago. Between these uplands we have the granite massifs of southwest Borneo, which separate the folds of the eastern part of this island into two zones, one extending toward the west and the other toward the south, the massifs of granite, gneiss, and crystalline schists of Central Celebes and the horsts of Boeroe and Ceram which, together with others, are probably part of an old massif (Suess, Vol. III, Part 3, p. 1036).

It is only southward from latitude $22^{\circ}S.$, along the eastern coast of Australia on one side, and northward from the Shan states, North Annam, and Yun Nan on the other side, that the Silurian and Devonian appear. Then, on the northern side, more to the north, exists the Cambrian and the pre-Cambrian beneath. The latter plays an important part to the south, but still more north of the Tsing-ling-chan in China. On the southern side (*viz.*, in Australia), however, these last-mentioned two formations do not appear.

In the intermediate territory, to which the archipelago belongs, outcrops of old crystalline schists occur in many places, but no explorer has discovered any fossils of the Old Paleozoic.

The Old Paleozoic series which border the periphery of the above-mentioned territory are strongly folded. The geo-metamorphic processes in those areas, that are nevertheless characterized by their fossils, have certainly not been less powerful than in the intermediate territory stretching from latitude 20°N. to latitude 22°S. , over the southeastern part of Asia, the Dutch East Indian Archipelago, New Guinea, and part of Australia.

Is it then credible that in this extensive territory, the extent of which from southwest to northeast is not known, all fossils of the Old Paleozoic should have disappeared? What particular reasons not valid for Southeastern Asia and Eastern and South-eastern Australia, could plausibly explain their disappearance? Is it not more logical to consider, under these circumstances, the absence of fossils, not as an indirect proof, but as a powerful argument for the hypothesis that in the above-outlined territory there never existed any Old Paleozoic fossils?

Is it not in the same way remarkable that the same transgression of the Upper Carboniferous and the Permian over the folded and denuded folds of the Old Paleozoic, which has been observed as well in Southeastern Asia as in Eastern Australia, is also apparent in some parts of the intermediate territory (for instance, in the west of Sumatra and in the island of Timor), whereas fossils of the Old Paleozoic have nevertheless not been found there?

From the above-stated considerations it seems not only possible to deduce a precise conclusion about the age of the crystalline schists formation, but also to deduce others of essential interest. They are the following:

1. The gneiss, the mica schists, the phyllites, and the real "old" schists (thus with the omission of the rocks which do not make part of them) must be Archean and pre-Cambrian rocks.

2. They once built up an Old Paleozoic continent, which extended at least over an area of 45° in latitude, between the tropics, from the southeast of Asia to the east of Australia. Its development from southwest to northeast is unknown, owing to the presence of the Indian and Pacific oceans, but at all events this continent must have included most of Sumatra on the southeast, and the Philippine Islands on the northeast, considering that, in

those countries too, there has not yet been found any fossil of the Old Paleozoic. To the west, it may have stretched out as far as Madagascar.

3. In the central part, north and south of the equator, mountain ranges of an almost east-west direction must have played an important part in this very old continent.

4. The Cambrian deposits on the north leaned against it, but in the south they have not been found. Nevertheless they may have existed south of Australia, where the ocean now is.

5. In the north, to a large extent toward the south, and in the south, fairly far toward the north, a transgression passed over the border areas of this continent during the Silurian, the Devonian, and the Lower Carboniferous periods (with a secondary unconformability).

6. Then a folding occurred of these sediments of the Old Paleozoic. Border ranges were formed at the periphery of the old continent which, from a tectonic point of view, are similar to the Tertiary Cordilleras.

7. During the Middle Carboniferous, denudation and leveling took place.

8. Lastly, the transgressions of the Upper Carboniferous and the Lower Permian seas invaded (with a real unconformability), not only the denuded Eopaleozoic border ranges, but also part of the old continent itself.

To this continent, the existence of which during the Old Paleozoic seems to be evident, I give the name of *Aequinoctia*.

It was during the Permo-Carboniferous that its dislocation began, in the territory of the Dutch East Indian Archipelago. The demembration of this oldest continent must have continued during the Mesozoic and the Tertiary; and so it became, in time, one of the most unsteady parts of the earth's crust. In this connection it is interesting to observe that the territory of the archipelago exhibits nowhere the tremendous development of the Mesozoic which has been observed, for instance, in the Alps, though uninterrupted sedimentation has taken place in some regions during the whole Mesozoic and part of the Tertiary. As a rule, however, complete series appear hardly anywhere. This

peculiarity can best be explained, I venture to suggest, by the aforesaid demembration of the original old territory.

A last question before concluding: Is it probable, in the future, that there may still be discovered in this territory fossils of the Old Paleozoic? Will it be the same with *Aequinoctia* as with the Jurassic Sino-Australian continent of Neumayr?

The numerous explorers who have worked in so many different parts of this region, still so unknown in the time of Neumayr, have succeeded in the course of years in making known, as we have seen, in a fairly continuous series, every period from the Upper Carboniferous to the Recent. Older fossils have not as yet been discovered, notwithstanding the greatest efforts and the closest attention, and in spite of the fact that the rocks preceding the Upper Carboniferous outcrop in large areas and are frequently deeply cut by erosion, thus offering very favorable points of investigation. Under these circumstances, I suppose that the hypothesis of the existence of *Aequinoctia* during the Old Paleozoic may be maintained.